Physica A 392 (2013) 5920–5938

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Behavioural breaks in the heterogeneous agent model: The impact of herding, overconfidence, and market sentiment☆

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HIGHLIGHTS

- We aim to incorporate findings from behavioural finance into a HAM.
- Herding, overconfidence, and market sentiment are studied in numerical analysis.
- Interesting price pattern of 30 DJIA constituents is revealed.
- Simulations replicate price behaviour found in the data during turbulent periods.

ARTICLE INFO

Article history:
Received 7 January 2013
Received in revised form 6 May 2013
Available online 7 August 2013

Keywords:
Heterogeneous agent model
Behavioural finance
Herding
Overconfidence
Market sentiment
Stock market crash

ABSTRACT

The main aim of this work is to incorporate selected findings from behavioural finance into a Heterogeneous Agent Model using the Brock and Hommes (1998) [34] framework. Behavioural patterns are injected into an asset pricing framework through the so-called 'Break Point Date', which allows us to examine their direct impact. In particular, we analyse the dynamics of the model around the behavioural break. Price behaviour of 30 Dow Jones Industrial Average constituents covering five particularly turbulent US stock market periods reveals interesting patterns in this aspect. To replicate it, we apply numerical analysis using the Heterogeneous Agent Model extended with the selected findings from behavioural finance: herding, overconfidence, and market sentiment. We show that these behavioural breaks can be well modelled via the Heterogeneous Agent Model framework and they extend the original model considerably. Various modifications lead to significantly different results and model with behavioural breaks is also able to partially replicate price behaviour found in the data during turbulent stock market periods.

1. Introduction

The representative agent approach and the Efficient Market Hypothesis [1] together with the Rational Expectations Hypothesis [2,3], which have dominated the field in the past, are being replaced by more realistic agent based computational approaches in recent literature. These movements in economic thought are reflected in a subset of agent based models, referred to as Heterogeneous Agent Models (HAM henceforth), abandoning agents' full rationality. Agents do not become

☆ We are grateful to Lukas Vacha for many useful discussions. The support from the Czech Science Foundation under the 402/09/0965 project and Grant Agency of the Charles University under the 588912 project is gratefully acknowledged.

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0378-4371/$ – see front matter
http://dx.doi.org/10.1016/j.physa.2013.07.050

irrational but 'boundedly rational' [4–6], they possess heterogeneous expectations, use simple forecasting rules to predict future development of market prices and the accuracy of their decisions is evaluated retroactively. Based on the simple profitability analysis, agents switch between several trading strategies—the parallel with the human learning process is more than apparent. Market fractions thus co-evolve over time and interactions between agents endogenously influence market prices which are no longer driven by exogenous news only.

Behavioural finance can be viewed as another answer to unrealistic assumptions of the Efficient Market Hypothesis. It suggests to employ the insights from behavioural sciences such as psychology and sociology into financial market models dating initial work back to the 1970s [7,8]. Just as HAM do, behavioural finance also builds on the bounded rationality and argues that some phenomena observed in the financial world can be better explained using models with agents which are not fully rational. Some authors even suggest the "*behavioural origin of the stylised facts of financial returns*", and of the "*statistical regularities of the data*" [9, pp. 19 & 39]. These psychological findings may have significant impacts on the theory of stock trading as they directly violate the Efficient Market Hypothesis [10].

Both approaches – HAM and behavioural finance – complement one another and could be used together as HAM framework could serve as a useful theoretical tool for verification of findings from behavioural finance. LeBaron [11, p. 41] argues that "*agent-based technologies are well suited for testing behavioural theories*" and anticipates that "*the connections between agent-based approaches and behavioural approaches will probably become more intertwined as both fields progress*". Moreover, many studies have highlighted different behavioural patterns as an optimal way of motivating the underlying HAM assumptions of strategy switching and heterogeneous beliefs. Barberis and Thaler [12] and Scheinkman and Xiong [13] mention overconfidence, De Grauwe and Grimaldi [14] and Boswijk et al. [15] suggest market sentiment, and Chang [16] and Chiarella et al. [17] put stress on herding behaviour.

Being an interdisciplinary research on the edge of economics and other fields such as psychology, sociology, and especially physics, interacting agents attracted researchers from many fields. Kaizoji et al. [18] innovate a spin model motivated by the Ising model [19,20] and apply it to interpret the magnetisation in terms of financial markets and to study the mechanisms creating bubbles and crashes. Westerhoff [21] discusses the role of emotions such as greed and fear in the determination of stock prices. The work of Dong [22] extends an interacting herding model by the clustering tendency of agents. An innovative approach introduced in Shimokawa et al. [23] studies the loss-aversion features embedded into an agent-based model. Authors show many consistencies with stylised facts and 'puzzles' in financial markets and demonstrate that a rise of loss-aversion amplifies the price distortions. Lamba and Seaman [24] propose an original threshold approach to the heterogeneous agent modelling within which the strategy of an agent is defined by a pair of moving thresholds around the current price. This method allows to include various types of agent motivations and behaviours in a consistent manner. Liu et al. [25] consider an effect of the HAM market microstructure, clearing house frequency, and behavioural assumptions on the differences between high-frequency returns and daily returns. Kaltwasser [26] presents another simple HAM, where traders have different beliefs about the fundamental rate. The model includes only fundamentalists and even in the absence of trend followers, cyclical fluctuations of the exchange rate can emerge. Most recently, Diks et al. [27] study the effect of memory in the framework of the simple HAM with agents switching between costly innovation and cheap imitation strategies. The authors highlight the fact, that although memory is commonly acknowledged to reduce the variance of prices and quantitatively stabilise the model, it can also have a qualitatively destabilising effect. We leave other interesting results of this interdisciplinary research [28–33] for the reader's inquisitiveness.

The central idea of our work is therefore to take advantage of both approaches and to interconnect particular findings from behavioural finance with heterogeneous expectations in an asset pricing framework in order to study resulting price dynamics. By doing so, we also investigate whether current HAM methodology can be reasonably extended by applying findings from the field of behavioural finance. Or conversely, whether HAM can serve as a tool for theoretical verification of these findings. Considering HAM methodology, we follow the Brock and Hommes [34] model approach and its extensions. From the plethora of well documented behavioural biases we examine the impact of herding, overconfidence, and market sentiment as these are generally supposed to have a strong impact on traders' behaviour not only during turbulent periods. Standard statistical tools of data analysis together with computational simulations are employed. Specifically, we aim at answering the question of whether selected findings from behavioural finance can be well modelled via the HAM, extend it and finally replicate price behaviour of real world market data.

For this purpose, we collect a unique dataset of 30 Dow Jones Industrial Average constituents covering five particularly turbulent stock market periods. The sample we consider starts with Black Monday 1987, the largest one-day stock market drop in history, and terminates with the Lehman Brothers Holdings bankruptcy in 2008, one of the milestones of the recent financial crisis of 2007–2010. We aim at studying the price behaviour around the crash days. In the second part of the work, we develop a simulation based framework where we inject selected behavioural findings into the HAM and study the behaviour of simulated prices around this break point.

The work is structured as follows. After the Introduction, we motivate selected findings from behavioural finance we would like to study and we offer a description of the Brock and Hommes [34] heterogeneous model framework. Next, we study a dataset of different financial crises periods and we find similarities in changes before and after the market crash. Finally, we pay our attention to the numerical analysis and simulation techniques used to study behavioural changes in the HAM.